



(11) **EP 3 006 301 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
13.04.2016 Bulletin 2016/15

(21) Application number: **14803604.9**

(22) Date of filing: **29.05.2014**

(51) Int Cl.:
B61K 13/00 ^(2006.01) **G01M 17/007** ^(2006.01)
G01M 17/08 ^(2006.01) **G08B 21/00** ^(2006.01)
G08B 31/00 ^(2006.01)

(86) International application number:
PCT/JP2014/064345

(87) International publication number:
WO 2014/192897 (04.12.2014 Gazette 2014/49)

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA ME

(30) Priority: **29.05.2013 JP 2013113265**

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(54) **DERAILMENT SIGN DETECTION SYSTEM, CONTROL DEVICE, DERAILMENT SIGN
DETECTION METHOD, AND DERAILMENT SIGN DETECTION PROGRAM**

(57) The pitch angular velocity of a truck and the roll angular velocity of the truck which have been detected by an angular velocity sensor (5) provided in a train in order to detect the pitch angular velocity and roll angular velocity of the traveling train are stored in a memory (32), the predicted value of the roll angular velocity after a lapse of a predetermined time is calculated on the basis of the history of the roll angular velocity, when the pitch angular velocity of the truck, which has been detected by the angular velocity sensor, and the predicted value of the roll angular velocity exceed preset threshold values, respectively, a derailment sign of the train is determined, and when the derailment sign is determined, the derailment sign is reported to the outside.

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FIG. 1A

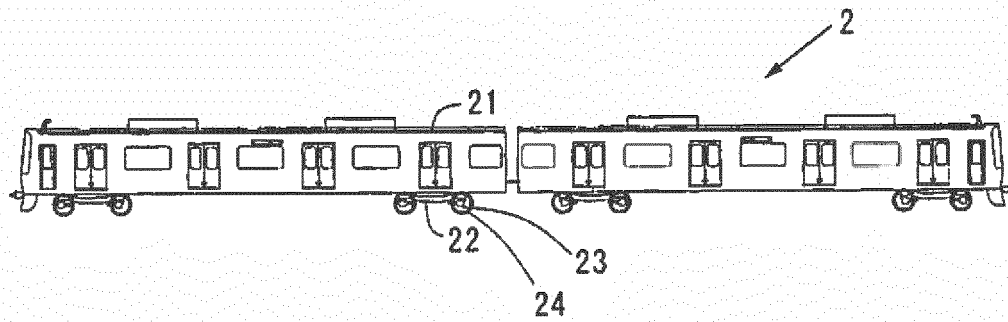
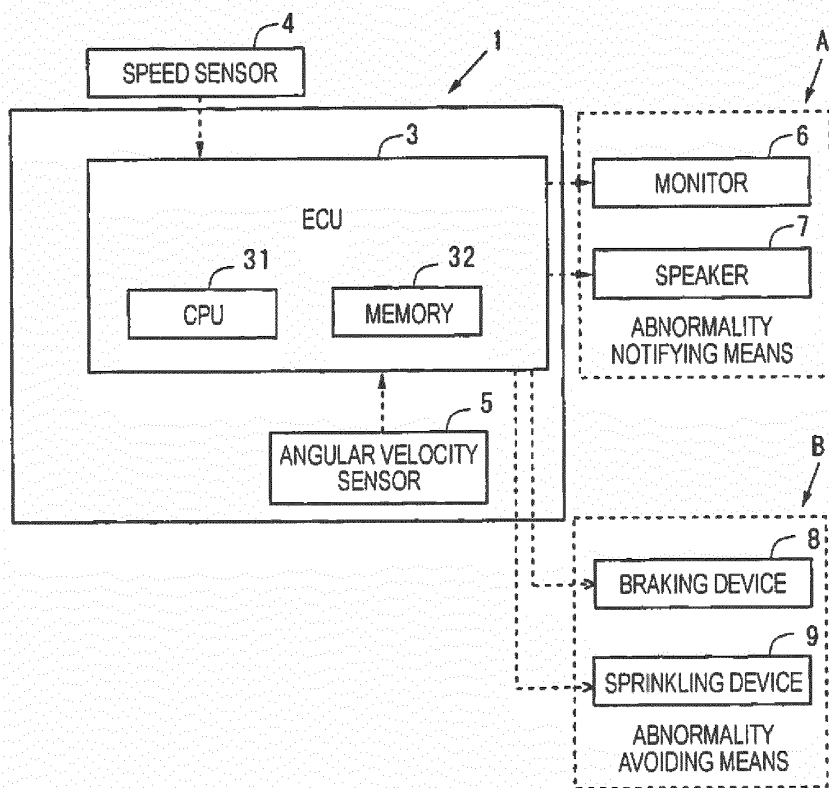


FIG. 1B



Description

Technical Field

[0001] The present invention relates to a derailment sign detection system, a control device, a derailment sign detection method and a derailment sign detection program.

Background Art

[0002] As a technology for detecting a derailment sign of a railway train, the technology described in Patent Document 1 is available. The technology described in Patent Document 1 is a technology proposed by the inventors of the present invention in which the pitch angular velocity and the roll angular velocity of a traveling bogie is detected using a sensor installed on the bogie frame and it is determined that a derailment sign is present under the condition that the detected pitch angular velocity of the bogie or the integrated value of the pitch angular velocity of the bogie becomes larger than a preset threshold value and under the condition that the detected roll angular velocity of the bogie or the integrated value of the roll angular velocity of the bogie becomes larger than a preset threshold value.

Citation List

Patent Document

[0003] Patent Document 1: WO 2010/064453

Summary of Invention

Technical Problem

[0004] With the above-mentioned technology described in Patent Document 1, a dangerous state can be grasped beforehand, whereby the safety during the traveling of a train can be improved. Furthermore, the derailment of the train can be prevented during traveling at low speed, whereby the breakage of the train and railway tracks can be prevented. On the other hand, as a result of further analysis of the past accident investigations, it has been confirmed that the time from the start of the so-called flange climb, i.e., a derailment sign, to a derailment is shorter than the time that is conventionally assumed to be required.

[0005] The present invention is made in consideration of the above-mentioned problems, and an object of the present invention is to provide a technology capable of determining the presence of a derailment sign earlier than ever.

Solution to Problem

[0006] In the present invention, attention is paid to the

roll angular velocity of a traveling bogie and the presence of a derailment sign is determined on the basis of the prediction value of the roll angular velocity to solve the above-mentioned problems.

[0007] More specifically, the present invention relates to a derailment sign detection system equipped with:

a detection section provided in a train to detect a pitch angular velocity and a roll angular velocity of a train on traveling;

a control device that makes a storage device store the roll angular velocity detected by the detection section, calculates a prediction value of the roll angular velocity after a lapse of a prediction time based on a history of the roll angular velocity, and determines that a derailment sign of the train is present in a case that the pitch angular velocity detected by the detection section and the prediction value of the roll angular velocity exceed preset threshold values respectively corresponding thereto; and

an output section that transmits the derailment sign to an outside in a case that the control device determines that the derailment sign is present.

[0008] In the present invention, the prediction value of the roll angular velocity is calculated and it is determined whether a derailment sign of the train is present on the basis of the prediction value of the roll angular velocity, whereby the time until the roll angular velocity exceeds the preset threshold value can be made shorter than ever. Hence, the presence of the derailment sign can be determined earlier. As a result, a dangerous state can be grasped earlier beforehand, whereby the safety during the traveling of the train can be improved. Furthermore, the derailment of the train can be prevented, and the breakage of the train and the railway tracks can be prevented.

[0009] For example, in the technology described in Patent Document 1, it is determined that a derailment sign is present under the condition that the pitch angular velocity of the bogie or the integrated value of the pitch angular velocity of the bogie becomes larger than a preset threshold value corresponding thereto and under the condition that the detected roll angular velocity of the bogie or the integrated value of the roll angular velocity of the bogie becomes larger than a preset threshold value corresponding thereto. In addition, time T1 until the detected roll angular velocity of the bogie or the integrated value of the roll angular velocity of the bogie becomes larger than the corresponding preset threshold value is longer than time T2 until the pitch angular velocity of the bogie or the integrated value of the pitch angular velocity of the bogie becomes larger than the corresponding preset threshold value ($T1 > T2$). In the present invention, attention is paid to the roll angular velocity that requires a relatively longer time for determination, and the prediction value of the roll angular velocity is used instead of the measured roll angular velocity so that the time until

the roll angular velocity exceeds the preset threshold value can be made shorter than ever.

[0010] The preset threshold value can be calculated by an experiment or a simulation in which the traveling speed of the train and the attribute parameters of the train have been set appropriately. The derailment sign is transmitted by sound or display, for example. Upon determining that a derailment sign is present, the control device may start a sprinkling device to sprinkle water to the contact portion between the rail and the flange of the wheel and to reduce the friction coefficient. As a result, the train can be made to return to the rails and can be prevented from being derailed. Alternatively, the control device may stop the train.

[0011] In addition, the control device may calculate a change amount of the roll angular velocity in an inclination measurement time, and may calculate the prediction value of the roll angular velocity after the lapse of the prediction time on an assumption that a change in the roll angular velocity is maintained after the lapse of the prediction time. Hence, it is possible to determine the presence of a derailment sign at a time earlier than the time when the roll angular velocity actually exceeds the preset threshold value corresponding thereto.

[0012] Furthermore, it is preferable that the prediction time and the inclination measurement time should be set based on a time required until the pitch angular velocity exceeds the preset threshold value of the pitch angular velocity. The time required until the pitch angular velocity exceeds the preset threshold value of the pitch angular velocity can be calculated by an experiment or a simulation in which the traveling speed of the train and the attribute parameters of the train have been set appropriately. It is preferable that the prediction time should be set so that the difference between the prediction time and the time required until the pitch angular velocity exceeds the preset threshold value of the pitch angular velocity.

[0013] Moreover, the control device can make the storage device store the pitch angular velocity detected by the detection section, can calculate the prediction value of the pitch angular velocity after the lapse of the prediction time based on a history of the pitch angular velocity, and can determine that the derailment sign of the train is present in a case that the prediction value of the pitch angular velocity and the prediction value of the roll angular velocity exceed the preset threshold values respectively corresponding thereto.

[0014] The present invention may herein be specified as the control device in the above-mentioned derailment sign detection system. For example, the present invention is a control device that makes a storage device store the roll angular velocity of a bogie detected by a detection section which is provided in a train and detects a pitch angular velocity and the roll angular velocity of the train on traveling, calculates a prediction value of the roll angular velocity after a lapse of a prediction time based on a history of the roll angular velocity, determines that a derailment sign of the train is present in a case that the

pitch angular velocity of the bogie detected by the detection section and the prediction value of the roll angular velocity exceed preset threshold values respectively corresponding thereto, and transmits the derailment sign to an outside in a case that the control device determines that the derailment sign is present.

[0015] Besides, the present invention may be specified as a derailment sign detection method to be executed by the above-mentioned derailment sign detection system or control device. For example, the present invention is a derailment sign detection method in which a computer executes a process including:

a prediction value calculating step of making a storage device store a roll angular velocity of a bogie detected by a detection section which is provided in a train and detects a pitch angular velocity and the roll angular velocity of the train on traveling, and calculating a prediction value of the roll angular velocity after a lapse of a prediction time based on a history of the roll angular velocity;

a sign determination step of determining that a derailment sign of the train is present in a case that the pitch angular velocity of the bogie detected by the detection section and the prediction value of the roll angular velocity calculated at the prediction value calculating step exceed preset threshold values respectively corresponding thereto; and

a transmitting step of transmitting the derailment sign to an outside in a case that it is determined that the derailment sign is present at the sign determination step.

[0016] What's more, the present invention may be specified as a derailment prediction detection program capable of being executed by the above-mentioned derailment sign detection system or control device. For example, the present invention is a derailment sign detection program for making a computer execute a process including:

a prediction value calculating step of making a storage device store a roll angular velocity of a bogie detected by a detection section which is provided in a train and detects a pitch angular velocity and the roll angular velocity of the train on traveling, and calculating a prediction value of the roll angular velocity after a lapse of a prediction time on based on a history of the roll angular velocity;

a sign determination step of determining that a derailment sign of the train is present in a case that the pitch angular velocity of the bogie detected by the detection section and the prediction value of the roll angular velocity calculated at the prediction value calculating step exceed preset threshold values respectively corresponding thereto; and

a transmitting step of transmitting the derailment sign to an outside in a case that it is determined that the

derailment sign is present at the sign determination step.

Still further, the present invention may be a recording medium that can be read by a computer. In this case, when the program stored in the recording medium is loaded into a computer or the like and executed, the function thereof can be provided. Recording media that can be read by computers or the like are recording media in which information including data and programs can be stored electrically, magnetically, optically, mechanically or chemically and can be read by computers or the like.

Advantageous Effect of Invention

[0017] The present invention can provide a technology capable of determining the presence of a derailment sign earlier than ever.

Brief Description of Drawings

[0018]

FIG. 1A is a side view showing a train;

FIG. 1B is a view showing a general configuration of a derailment sign detection system according to an embodiment;

FIG. 2A is a plan view showing an installation example of a sensor in the derailment sign detection system according to the embodiment;

FIG. 2B is a side view showing the installation example of the sensor in the derailment sign detection system according to the embodiment;

FIG. 3 shows an algorithm for derailment sign detection;

FIG. 4 shows a flow of a derailment sign detection determination process according to the embodiment;

FIG. 5 shows an example of a graph illustrating the relationship between a change amount and time;

FIG. 6 shows an example of a database of threshold values;

FIG. 7 shows an example of a prediction effect in the movement average of roll angular velocity;

FIG. 8 shows an example of a prediction effect in pitch angular velocity;

FIG. 9 shows parameter values for a simulation;

FIG. 10 shows verification result (1) of detection time;

FIG. 11 shows verification result (2) of detection time;

FIG. 12 shows verification result (3) of detection time;

FIG. 13 shows verification result (4) of detection time;

FIG. 14 shows verification result (5) of detection time;

FIG. 15 shows verification result (6) of detection time;

FIG. 16 shows verification result (7) of detection time;

FIG. 17 shows verification result (8) of detection time;

FIG. 18 shows verification result (9) of detection time;

and

FIG. 19 shows verification result (10) of detection

time.

Description of Embodiment

[0019] Next, an embodiment according to the present invention will be described on the basis of the drawings. However, the following descriptions are only examples and the present invention is not limited to these.

<Embodiment>

«Configuration»

[0020] As shown in FIGS. 1A and 1B, a derailment sign detection system 1 according to an embodiment is a system composed of various electronic apparatuses and various sensors provided in a train 2, and the system is equipped with an ECU 3, a speed sensor 4 and an angular velocity sensor 5. The train 2 is equipped with vehicle bodies 21 and bogies 22 connected to the lower sections of the vehicle bodies 21 to support the vehicle bodies 21. The bogie 22 is equipped with a bogie frame (not shown in FIG. 1A). In the bogie frame, axles 23 are provided so as to be extended across the bogie frame and wheels 24 making contact with rails are connected to both ends of each axle 23. The derailment sign detection system 1 may be configured so as to further include at least an abnormality notifying means A (a monitor 6, a speaker 7) or an abnormality avoiding means B (a braking device 8, a water sprinkling device 9).

[0021] The ECU (Electronic Control Unit) 3 corresponds to a control device according to the present invention and is equipped with a CPU (Central Processing Unit) 31 and a memory 32. The ECU 3 is connected to the speed sensor 4, the angular velocity sensor 5, the abnormality notifying means A (the monitor 6, the speaker 7) and the abnormality avoiding means B (the braking device 8, the water sprinkling device 9). The CPU 31 calculates the prediction value of a roll angular velocity and determines whether a derailment sign of the train is present, for example, according to a program stored in the memory 32. Furthermore, the CPU 31 controls the abnormality notifying means A (the monitor 6, the speaker 7) and the abnormality avoiding means B (the braking device 8, the water sprinkling device 9), for example. The process to be executed by the ECU 3 will be described later in detail.

[0022] The speed sensor 4 detects the traveling speed of the train 2. The speed sensor 4 is provided, for example, on the axle 23, detects the number of revolutions of the wheel 24 per unit time and outputs the number of revolutions to the ECU 3, thereby outputting the traveling speed of the train 2 to the ECU 3.

[0023] The angular velocity sensor 5 is provided on the bogie frame 25 of the bogie 22 at a nearly central section in the front-rear direction of the train 2 and on a side section in the width direction of the train 2 and detects a pitch angular velocity and a roll angular velocity. The pitch

angular velocity is the angular velocity of the pitch (the rotation (or inclination) around an axis in the width direction of the train), and the roll angular velocity is the roll (the rotation (or inclination) around an axis in the front-rear direction of the train). An existing sensor, such as a gyroscope, can be used appropriately for the angular velocity sensor 5.

[0024] When the ECU 3 determines that a derailment sign is present, the monitor 6 is controlled by the ECU 3 and displays a derailment sign detection state. The monitor 6 is an example of an output section of the present invention and can be disposed, for example, in the vicinity of the driver seat of the train 2.

[0025] When the ECU 3 determines that a derailment sign is present, the speaker 7 outputs a derailment sign detection state as sound under the control of the ECU 3. The speaker 7 is an example of the output section of the present invention and can be disposed, for example, in the vicinity of the driver seat of the train 2.

[0026] The sprinkling device 9 is controlled by the ECU 3, and, for example, when a derailment sign is detected, the sprinkling device sprinkles water to the contact portion between the rail and the flange of the wheel to reduce the friction coefficient, thereby to make the derailed train 2 return to the rails. Alternatively, the braking device 8 is controlled by the ECU 3 to stop the train.

«Derailment sign determination process»

[0027] Next, a derailment sign determination process will be described below. FIG. 3 shows an algorithm for derailment sign detection. In addition, FIG. 4 shows a flow of a derailment sign determination process according to the embodiment. The derailment sign determination process is executed by the reading of the corresponding program stored in the memory 32 using the CPU 31 of the ECU 3.

[0028] At step S01, the CPU 31 acquires information required for the derailment sign determination process. The information includes the traveling speed, pitch angular velocity and roll angular velocity of the train 2. The CPU 31 can detect the traveling speed of the train 2 using the speed sensor 4. The CPU 31 can detect the pitch angular velocity and the roll angular velocity using the angular velocity sensor 5 provided on the bogie frame 25 of the bogie 22. The acquired traveling speed, pitch angular velocity and roll angular velocity are stored in the memory 32. The CPU 31 can detect the traveling speed, pitch angular velocity and roll angular velocity of the train, for example, every 0.005 sec. This detection timing is just an example and can be set appropriately. Hence, the traveling speed, pitch angular velocity and roll angular velocity to be acquired every 0.005 sec are stored sequentially in the memory 32, whereby the histories of the traveling speed, pitch angular velocity and roll angular velocity are created. A logic for making a correction for eliminating the influence of cants on the basis of the roll angular velocity and a logic for making a correction for

eliminating the influence of rail joints on the basis of the pitch angular velocity are incorporated in a determination logic for executing the derailment sign determination process, whereby the influence of track irregularity on the derailment sign determination process can be eliminated. As a result, it is possible to determine whether not only a derailment sign during the traveling of the train 2 on straight rails but also a derailment sign during the traveling of the train 2 on curved rails is present. When the information required for the derailment sign determination process is acquired, the process advances to the next step.

[0029] At step S02, the CPU 31 calculates a prediction value of the roll angular velocity after the lapse of a predetermined time on the basis of the history of the roll angular velocity. For example, the CPU 31 accesses the area of the memory 32 in which the roll angular velocity is stored, acquires a predetermined number of roll angular velocity values from the roll angular velocity values stored in the memory 32 in order from the newest value to an older value depending on the storage time (FIG. 5 indicates that the roll angular velocity values Φ at five points included in an inclination measurement time Δt_p are acquired), obtains a recent average inclination $\Delta\Phi$ by integrating the roll angular velocity values and calculating the change amount (displacement amount) in the inclination measurement time, and calculates the movement average prediction value Φ_p of the roll angular velocity after the lapse of a prediction time T_p on the assumption that the recent average inclination is maintained constant. Expression 1 is an expression for calculating the prediction value of the roll angular velocity.

[Expression 1]

$$\Phi_p = \Phi + \Delta\Phi \times T_p$$

Φ_p : movement average prediction value of roll angular velocity

Φ : current movement average value

$\Delta\Phi$: recent average inclination

T_p : prediction time

[0030] The current movement average value can be calculated using Expression 2.

[Expression 2]

$$\Phi = \frac{1}{\Delta t_p} \int_{t-\Delta t_p}^t \phi(t) dt$$

$\phi(t)$: roll angular velocity

Δt_p : inclination measurement time

$$\Delta\Phi = d\Phi/\Delta t_p = (\Phi(t) - \Phi(t - \Delta t_p))/\Delta t_p$$

[0031] The above is represented by a graph as shown in FIG. 5. FIG. 5 shows an example of a graph illustrating the relationship between a change amount and time. As shown in FIG. 5, the recent average inclination $\Delta\Phi$ is obtained from the change amount (displacement amount, that is, $d\Phi/t_p$) of the roll angular velocity Φ at five time points included in the inclination measurement time Δt_p , and the movement average prediction value Φ_p of the roll angular velocity after the lapse of the prediction time T_p is calculated on the assumption that the recent average inclination is maintained constant. The movement average prediction value of the roll angular velocity calculated as described above is stored in the memory 32. After the movement average prediction value of the roll angular velocity is calculated as described above, the process advances to the next step.

[0032] At step S03, the CPU 31 determines whether a derailment sign is present. In the case that the prediction values of the pitch angular velocity and the roll angular velocity exceed preset threshold values respectively corresponding thereto, the CPU 31 determines that a derailment sign is present. The CPU 31 accesses the area of the memory 32 in which the pitch angular velocity is stored and acquires the pitch angular velocity. At this time, the CPU 31 accesses the newest value of the pitch angular velocity values stored in the memory 32. Although a case in which the CPU 31 acquires the pitch angular velocity stored in the memory 32 is described herein, it may be possible that the CPU 31 acquires the pitch angular velocity output from the angular velocity sensor 5.

[0033] On the other hand, the CPU 31 accesses the area of the memory 32 in which the prediction value of the roll angular velocity is stored and acquires the prediction value of the roll angular velocity. The threshold values of the pitch angular velocity and the roll angular velocity can be set at each traveling speed as shown in FIG. 6 and stored in the memory 32 beforehand. Hence, the CPU 31 accesses the area of the memory 32 in which the threshold values are stored to acquire the respective threshold value corresponding to the traveling speed value.

[0034] The respective threshold values can be calculated by an experiment or a simulation in which the traveling speed of the train and the attribute parameters of the train have been set appropriately. The attribute parameters include the weight of the train, the number of the axles and the diameter of the wheel, for example. Each threshold value can be set as the lowest value of a physical amount obtained immediately after a wheel rises up onto the rail, in consideration of detection omission and erroneous detection. For example, each threshold value can be set for each of vehicle conditions and traveling conditions including the conditions that the rising amount of the left wheel of the first axle is 10 mm, the traveling speed is 10 km/h and the number of the revolutions of the wheel until the rising amount of the wheel reaches 10 mm is one.

[0035] In the case that the pitch angular velocity exceeds the threshold value of the pitch angular velocity and the prediction value of the roll angular velocity exceeds the threshold value of the roll angular velocity, the CPU 31 determines that a derailment sign is present. In this case, the process advances to step S04. On the other hand, in the case that the CPU 31 does not determine that a derailment sign is present, the process returns to step S01. Then, the CPU 31 acquires the traveling speed, pitch angular velocity and roll angular velocity of the train 2 at step S01 and recalculates and updates the movement average prediction value Φ_p of the roll angular velocity at step S02, and performs the determination at step S03.

[0036] At step S04, the CPU 31 controls the water sprinkling device 9 to make the derailed train 2 return to the rails or controls the braking device 8 to stop the train 2. In addition, the detection of the derailment sign is indicated on the monitor 6 for warning. Furthermore, the detection of the derailment sign is output as sound through the speaker 7 for warning.

«Effect»

[0037] In the derailment sign detection system 1 according to the first embodiment, the prediction value of the roll angular velocity is calculated and it is determined whether a derailment sign of the train 2 is present on the basis of the prediction value of the roll angular velocity, whereby the time until the roll angular velocity exceeds the preset threshold value can be made shorter than ever. Hence, the presence of the derailment sign can be determined earlier. As a result, a dangerous state can be grasped beforehand, whereby the safety during the traveling of the train 2 can be improved. Consequently, the derailment of the train 2 can be prevented, and the breakage of the train and the railway tracks can be prevented. An example of the effect is shown in FIG. 7. The prediction effect in the case that the inclination measurement time is 0.05 sec and the prediction time is 0.20 sec is shown in FIG. 7, and the effect corresponds to Experiment No. 4 (see FIG. 13) of the simulation to be described later. According to FIG. 7, by the use of the prediction value of the roll angular velocity, the detection time of the derailment sign is shifted from point A to point B, thereby being shortened by approximately 100 ms.

<Simulation>

[0038] FIG. 9 shows parameter values for the simulation, and FIGS. 10 to 18 show verification results (1) to (9) of the detection time and show the detection time values in the case that the movement average prediction of the roll angular velocity is performed. On the assumption of an actual train, the simulation is performed at the inclination measurement time and the prediction time for sign prediction detection as shown in FIG. 10 to verify an optimal inclination measurement time and an optimal pre-

diction time while the respective parameter values are changed. It can be confirmed that the detection time is slightly decreased by decreasing the inclination measurement time and that the detection time is decreased by increasing the prediction time as shown in FIGS. 10 to 18. It can also be confirmed that the detection time in the case that the inclination measurement time is set to 50 [ms] and that the prediction time is set to 200 [ms] is almost equal to the detection time required for detecting a derailment sign using the pitch angular velocity. As described above, it is preferable that the prediction time and the inclination measurement time should be set so that the detection time required for detecting a derailment sign using the prediction value of the roll angular velocity is nearly equal to the detection time required for detecting a derailment sign using the pitch angular velocity.

<Modification>

[0039] In the first embodiment, the prediction value of the roll angular velocity is calculated and a derailment sign is detected using the prediction value of the roll angular velocity; however, the prediction value of the pitch angular velocity after the lapse of a predetermined time may be calculated using the pitch angular velocity on the basis of the history of the pitch angular velocity and the prediction value may be used for the detection of a derailment sign. The prediction value of the pitch angular velocity can be calculated; for example, the CPU 31 accesses the area of the memory 32 in which the pitch angular velocity is stored, acquires a predetermined number of pitch angular velocity values in order from the newest value to an older value depending on the storage time, obtains a recent average inclination by integrating the pitch angular velocity values and calculating the change amount in the inclination measurement time, and calculates the prediction value of the pitch angular velocity after the lapse of a predetermined time on the assumption that the change in the calculated recent average inclination is maintained after the lapse of the predetermined time. FIG. 8 shows an example of a prediction effect in the pitch angular velocity. The prediction effect in the case that the inclination measurement time is 0.05 sec and the prediction time is 0.20 sec is shown in FIG. 8, and the effect corresponds to Experiment No. 4 (see FIG. 19) of the simulation. FIG. 19 shows the detection result (10) of the detection time and shows the detection time in the case that the prediction of the pitch angular velocity is performed. According to FIG. 8, by the use of the prediction value of the pitch angular velocity, the detection time of the derailment sign is shifted from point A to point B, thereby being shortened by approximately 50 ms.

[0040] The various contents described above can be combined without departing from the scope of the technological concept of the present invention.

[0041] The characteristics of the above-mentioned embodiment of the derailment sign detection system,

control device, derailment sign detection method and derailment sign detection program according to the present invention will be briefly summarized and listed in the following items [1] to [6].

5 **[0042]**

[1] A derailment sign detection system equipped with:

10 a detection section (angular velocity sensor 5) provided in a train and detecting a pitch angular velocity and a roll angular velocity of the train on traveling;
a control device (ECU 3) that makes a storage device (memory 32) store the roll angular velocity detected by the detection section, calculates a prediction value (Φ_p) of the roll angular velocity after a lapse of a prediction time (T_p) based on a history of the roll angular velocity, and determines that a derailment sign of the train is present in a case that the pitch angular velocity detected by the detection section and the prediction value of the roll angular velocity exceed preset threshold values respectively corresponding thereto: and
an output section (abnormality notifying means A) that transmits the derailment sign to an outside in a case that the control device determines that the derailment sign is present.

[2] The derailment sign detection system described in the item [1], wherein the control device calculates a change amount of the roll angular velocity in an inclination measurement time (Δt_p) and calculates a prediction value of the roll angular velocity after the lapse of the prediction time on an assumption that a change in the roll angular velocity is maintained after the lapse of the prediction time.

[3] The derailment sign detection system described in the item [2], wherein the prediction time and the inclination measurement time are set based on a time required until the pitch angular velocity exceeds the preset threshold value of the pitch angular velocity.

[4] The derailment sign detection system described in any one of the items [1] to [3], wherein the control device makes the storage device store the pitch angular velocity detected by the detection section, calculates a prediction value of the pitch angular velocity after the lapse of the prediction time based on a history of the pitch angular velocity, and determines that a derailment sign of the train is present in a case that the prediction value of the pitch angular velocity and the prediction value of the roll angular velocity exceed the preset threshold values respectively corresponding thereto.

[5] A control device (ECU 3) configured to:

make a storage device (memory 32) store a roll angular velocity of a bogie (22) detected by a detection section (angular velocity sensor 5) which is provided in a train and detects a pitch angular velocity and the roll angular velocity of the train on traveling; 5
calculate a prediction value of the roll angular velocity after a lapse of a prediction time (T_p) based on a history of the roll angular velocity, determines that a derailment sign of the train is present in a case that the pitch angular velocity of the bogie detected by the detection section and the prediction value of the roll angular velocity exceed preset threshold values respectively corresponding thereto; and 10
transmit the derailment sign to an outside in a case that the control device determines that the derailment sign is present.

[6] A derailment sign detection method in which a computer (ECU 3) executes a process including:

a prediction value calculating step (step S02) of making a storage device (memory 32) store a roll angular velocity of a bogie (22) detected by a detection section (angular velocity sensor 5) which is provided in a train and detects a pitch angular velocity and the roll angular velocity of the train on traveling, and calculating a prediction value of the roll angular velocity after a lapse of a prediction time (T_p) based on a history of the roll angular velocity; 25
a sign determination step (step S03) of determining that a derailment sign of the train is present in a case that the pitch angular velocity of the bogie detected by the detection section and the prediction value of the roll angular velocity calculated at the prediction value calculating step exceed preset threshold values respectively corresponding thereto; and 30
a transmitting step (step S04) of transmitting the derailment sign to an outside in a case that it is determined that the derailment sign is present at the sign determination step. 35

[7] A derailment sign detection program for making a computer (ECU 3) execute a process including:

a prediction value calculating step (step S02) of making a storage device (memory 32) store a roll angular velocity of a bogie (22) detected by a detection section (angular velocity sensor 5) which is provided in a train and detects a pitch angular velocity and the roll angular velocity of the train on traveling, and calculating a prediction value of the roll angular velocity after a lapse of a prediction time (T_p) based on a history of the roll angular velocity; 50
55

a sign determination step (step S03) of determining that a derailment sign of the train is present in a case that the pitch angular velocity of the bogie detected by the detection section and the prediction value of the roll angular velocity calculated at the prediction value calculating step exceed preset threshold values respectively corresponding thereto; and
a transmitting step (step S04) of transmitting the derailment sign to an outside in a case that it is determined that the derailment sign is present at the sign determination step.

[0043] Although the present invention has been described in detail referring to the specific embodiment, it is obvious to those skilled in the art that the present invention can be changed and modified variously without departing from the spirit and scope of the present invention.

[0044] This application is based on Japanese Patent Application (patent application 2013-113265) filed on May 29, 2013, the entire contents of which are hereby incorporated by reference.

Industrial Applicability

[0045] With the present invention, the presence of a derailment sign can be determined earlier than ever. The present invention exhibiting this advantage is useful in the field relating to a derailment sign detection system, a control device, a derailment sign detection method and a derailment sign detection program.

Reference Signs List

[0046]

- 1 ... derailment sign detection system
- 2 ... train
- 3 ... ECU
- 4 ... speed sensor
- 5 ... angular velocity sensor
- A ... abnormality notifying means
- B ... abnormality avoiding means

Claims

1. A derailment sign detection system comprising:

a detection section provided in a train and detecting a pitch angular velocity and a roll angular velocity of the train on traveling;
a control device that makes a storage device store the roll angular velocity detected by the detection section, calculates a prediction value of the roll angular velocity after a lapse of a prediction time based on a history of the roll angular

- velocity, and determines that a derailment sign of the train is present in a case that the pitch angular velocity detected by the detection section and the prediction value of the roll angular velocity exceed preset threshold values respectively corresponding thereto; and
an output section that transmits the derailment sign to an outside in a case that the control device determines that the derailment sign is present.
2. The derailment sign detection system according to claim 1, wherein
the control device calculates a change amount of the roll angular velocity in an inclination measurement time, and calculates the prediction value of the roll angular velocity after the lapse of the prediction time on an assumption that a change in the roll angular velocity is maintained after the lapse of the prediction time.
3. The derailment sign detection system according to claim 2, wherein
the prediction time and the inclination measurement time are set based on a time required until the pitch angular velocity exceeds the preset threshold value of the pitch angular velocity.
4. The derailment sign detection system according to any one of claims 1 to 3, wherein
the control device makes the storage device store the pitch angular velocity detected by the detection section, calculates a prediction value of the pitch angular velocity after the lapse of the prediction time based on a history of the pitch angular velocity, and determines that the derailment sign of the train is present in a case that the prediction value of the pitch angular velocity and the prediction value of the roll angular velocity exceed the preset threshold values respectively corresponding thereto.
5. A control device, configured to:

make a storage device store a roll angular velocity of a bogie detected by a detection section which is provided in a train and detects a pitch angular velocity and the roll angular velocity of the train on traveling,
calculate a prediction value of the roll angular velocity after a lapse of a prediction time based on a history of the roll angular velocity,
determine that a derailment sign of the train is present in a case that the pitch angular velocity of the bogie detected by the detection section and the prediction value of the roll angular velocity exceed preset threshold values respectively corresponding thereto, and
transmit the derailment sign to an outside in a case that the control device determines that the derailment sign is present.
6. A derailment sign detection method in which a computer executes a process comprising:

a prediction value calculating step of making a storage device store a roll angular velocity of a bogie detected by a detection section which is provided in a train and detects a pitch angular velocity and the roll angular velocity of the train on travelling, and calculating a prediction value of the roll angular velocity after a lapse of a prediction time based on a history of the roll angular velocity;
a sign determination step of determining that a derailment sign of the train is present in a case that the pitch angular velocity of the bogie detected by the detection section and the prediction value of the roll angular velocity calculated at the prediction value calculating step exceed preset threshold values respectively corresponding thereto; and
a transmitting step of transmitting the derailment sign to an outside in a case that it is determined that the derailment sign is present at the sign determination step.
7. A derailment sign detection program for making a computer execute a process comprising:

a prediction value calculating step of making a storage device store a roll angular velocity of a bogie detected by a detection section which is provided in a train and detects a pitch angular velocity and the roll angular velocity of the train on travelling, and calculating a prediction value of the roll angular velocity after a lapse of a prediction time based on a history of the roll angular velocity;
a sign determination step of determining that a derailment sign of the train is present in a case that the pitch angular velocity of the bogie detected by the detection section and the prediction value of the roll angular velocity calculated at the prediction value calculating step exceed preset threshold values respectively corresponding thereto; and
a transmitting step of transmitting the derailment sign to an outside in a case that it is determined that the derailment sign is present at the sign determination step.

FIG. 1A

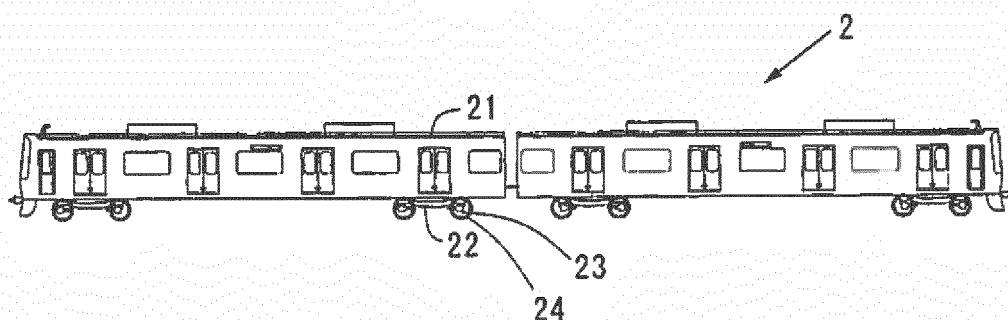


FIG. 1B

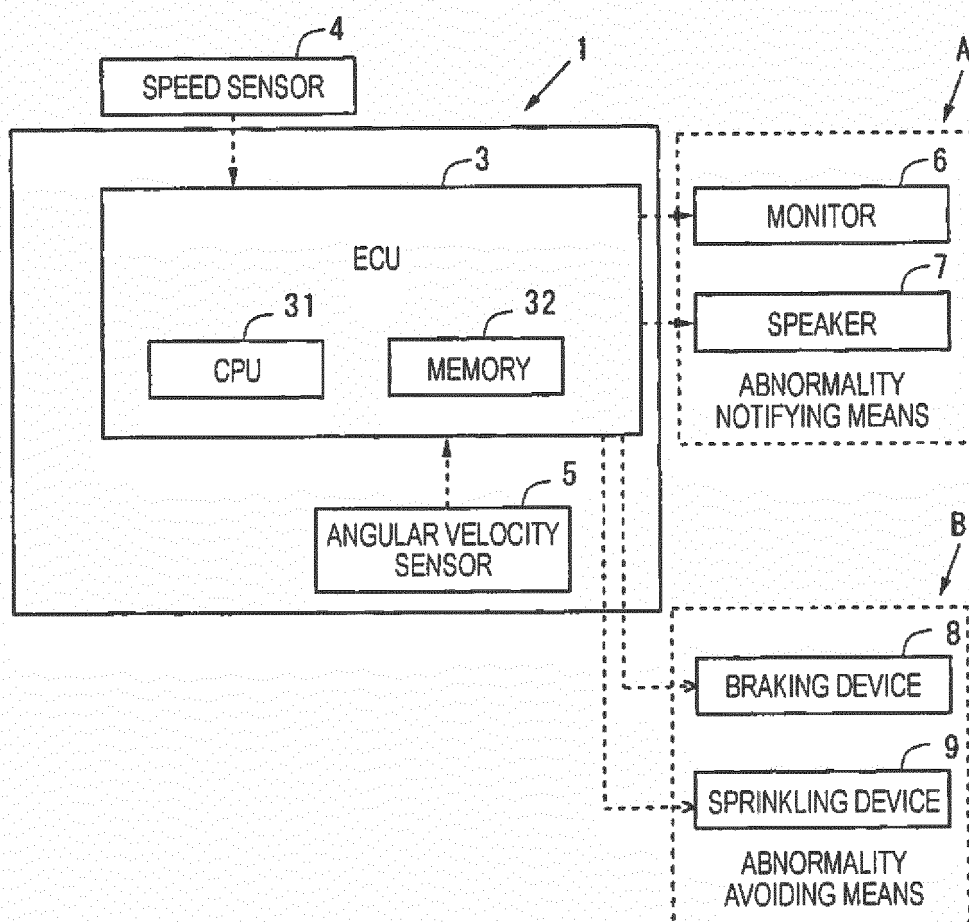


FIG. 2A

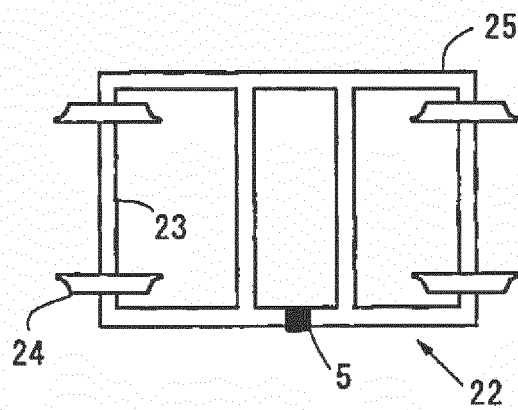


FIG. 2B

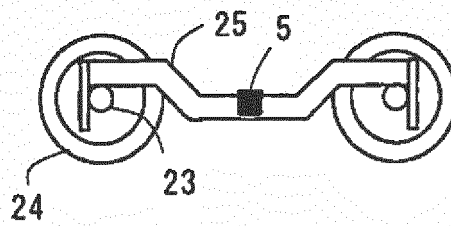


FIG. 3

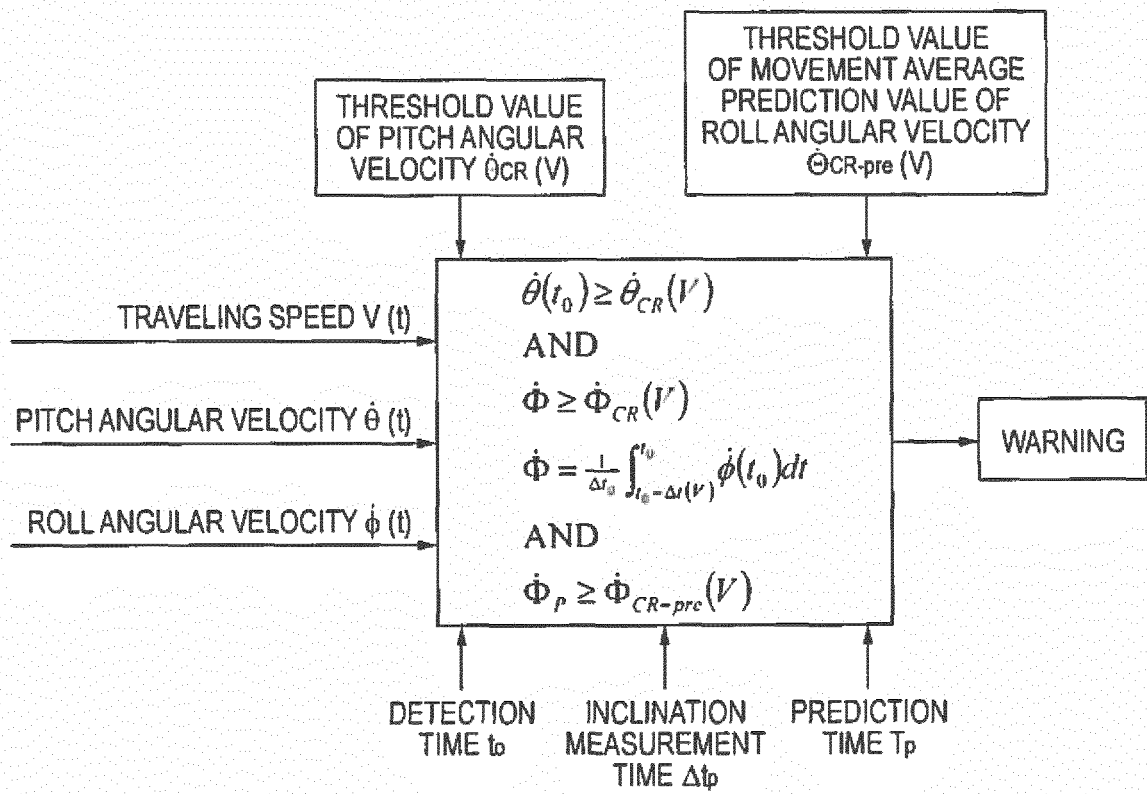


FIG. 4

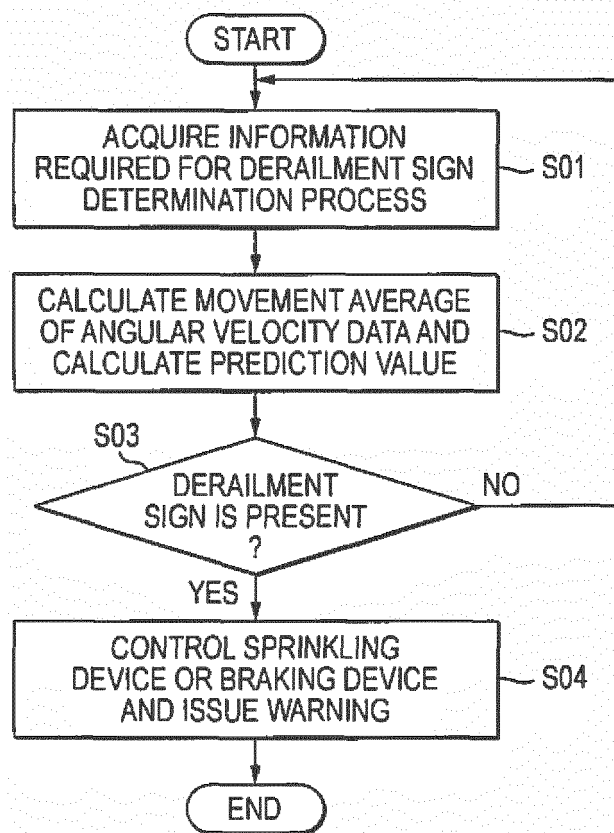


FIG. 5

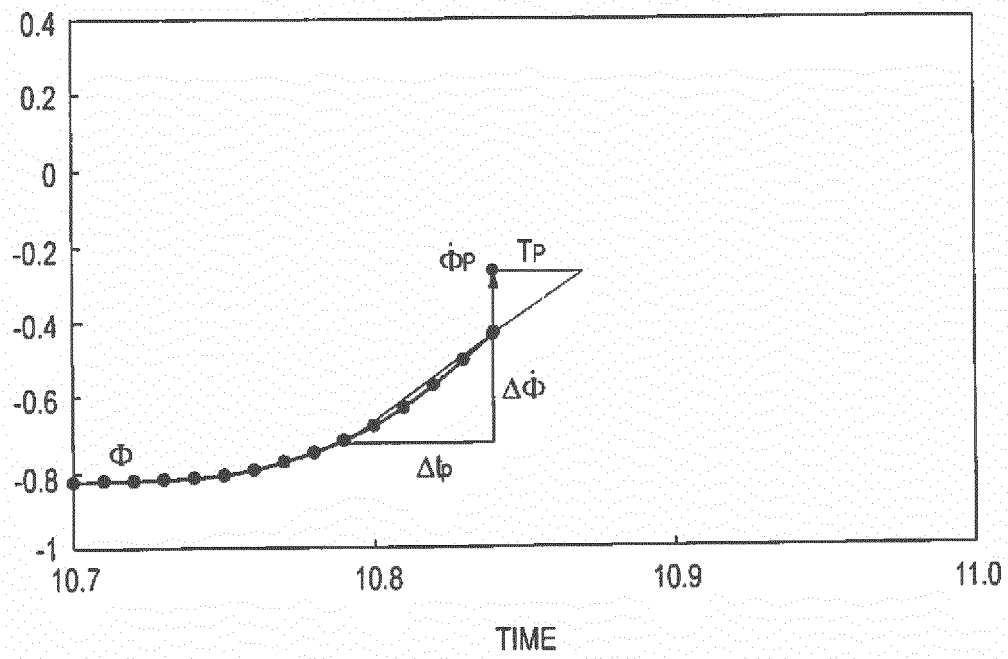
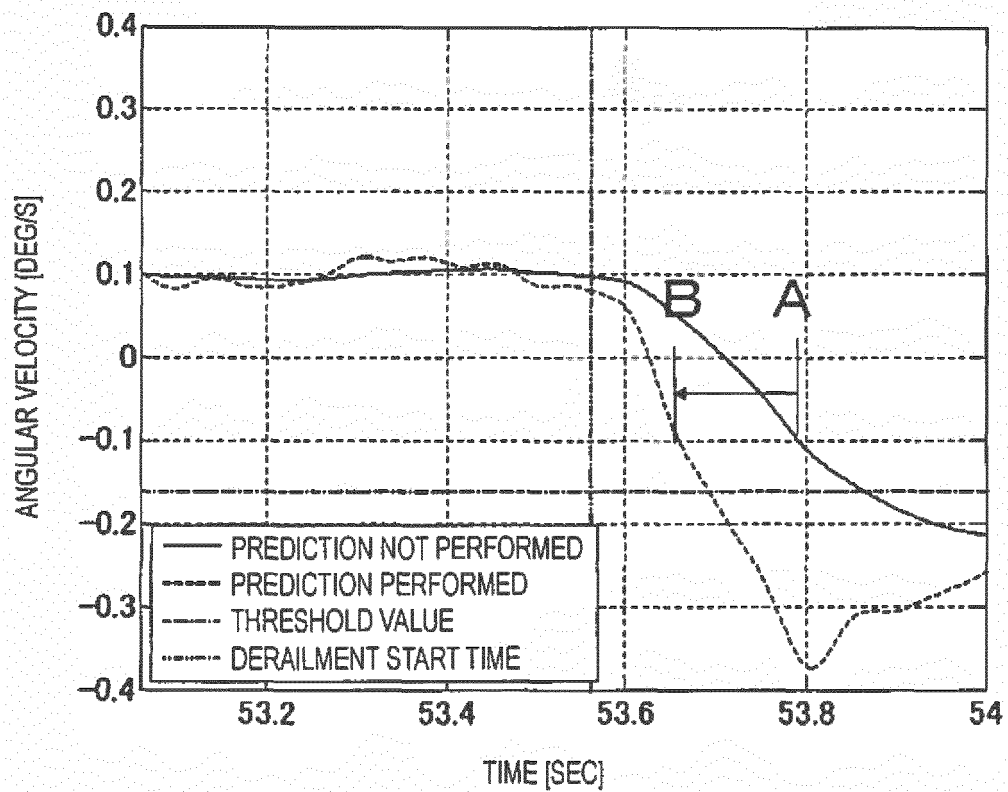


FIG. 6

TRAVELING SPEED	THRESHOLD VALUE OF PITCH ANGULAR VELOCITY	THRESHOLD VALUE OF ROLL ANGULAR VELOCITY
(km/h)	(deg/sec)	(deg/sec)
5	○○	○○
6	○○	○○
7	○○	○○
8	○○	○○
9	○○	○○
10	○○	○○
•	•	•
•	•	•
•	•	•

FIG. 7

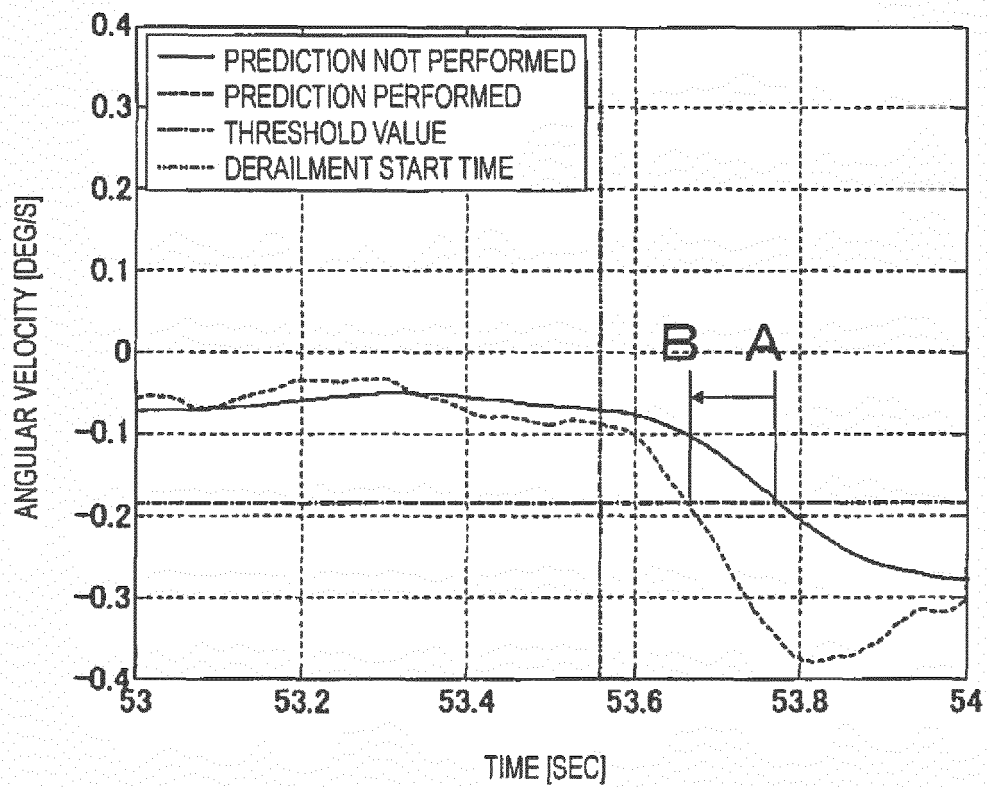
(EXAMPLE OF PREDICTION EFFECT IN
MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY)



SIMULATION CONDITIONS
EXPERIMENT NO. 4
INCLINATION MEASUREMENT TIME
 $\Delta t_p = 0.05$ [SEC]
PREDICTION TIME T_p
 $T_p = 0.20$ [SEC]

FIG. 8

(EXAMPLE OF PREDICTION EFFECT IN PITCH ANGULAR VELOCITY)



SIMULATION CONDITIONS
 EXPERIMENT NO. 4
 INCLINATION MEASUREMENT TIME
 $\Delta t_p = 0.05$ [SEC]
 PREDICTION TIME T_p
 $T_p = 0.20$ [SEC]

FIG. 9

INCLINATION MEASUREMENT TIME Δt_p	50.100.150 [ms]
PREDICTION TIME t_p	50.100.150.200 [ms]

FIG. 10

EXPERIMENT NO.		1	
FLANGE CLIMB SPEED		3.51km/H	
DETECTION TIME WITH NO PREDICTION OF PITCH ANGULAR VELOCITY		0.258 [SEC]	
DETECTION TIME WITH NO PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY		0.318 [SEC]	
DETECTION TIME WITH PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY			
PREDICTION TIME T_p	INCLINATION MEASUREMENT TIME Δt_p		
	0.05 [SEC]	0.10 [SEC]	0.15 [SEC]
0.05[SEC]	0.225 [SEC]	0.225 [SEC]	0.230 [SEC]
0.10 [SEC]	0.178 [SEC]	0.186 [SEC]	0.191 [SEC]
0.15 [SEC]	0.143 [SEC]	0.154 [SEC]	0.166 [SEC]
0.20 [SEC]	0.127 [SEC]	0.133 [SEC]	0.150 [SEC]

FIG. 11

EXPERIMENT NO.		2	
FLANGE CLIMB SPEED		5.27km/H	
DETECTION TIME WITH NO PREDICTION OF PITCH ANGULAR VELOCITY		0.256 [SEC]	
DETECTION TIME WITH NO PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY		0.371 [SEC]	
DETECTION TIME WITH PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY			
PREDICTION TIME T_p	INCLINATION MEASUREMENT TIME Δt_p		
	0.05 [SEC]	0.10 [SEC]	0.15 [SEC]
0.05[SEC]	0.307 [SEC]	0.271 [SEC]	0.273 [SEC]
0.10 [SEC]	0.207 [SEC]	0.213 [SEC]	0.221 [SEC]
0.15 [SEC]	0.176 [SEC]	0.186 [SEC]	0.195 [SEC]
0.20 [SEC]	0.152 [SEC]	0.162 [SEC]	0.178 [SEC]

FIG. 12

EXPERIMENT NO.		3	
FLANGE CLIMB SPEED		5.31km/H	
DETECTION TIME WITH NO PREDICTION OF PITCH ANGULAR VELOCITY		0.215 [SEC]	
DETECTION TIME WITH NO PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY		0.342 [SEC]	
DETECTION TIME WITH PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY			
PREDICTION TIME T_p	INCLINATION MEASUREMENT TIME Δt_p		
	0.05 [SEC]	0.10 [SEC]	0.15 [SEC]
0.05[SEC]	0.285 [SEC]	0.264 [SEC]	0.266 [SEC]
0.10 [SEC]	0.193 [SEC]	0.203 [SEC]	0.211 [SEC]
0.15 [SEC]	0.168 [SEC]	0.176 [SEC]	0.184 [SEC]
0.20 [SEC]	0.145 [SEC]	0.152 [SEC]	0.166 [SEC]

FIG. 13

EXPERIMENT NO.		4	
FLANGE CLIMB SPEED		7.5km/H	
DETECTION TIME WITH NO PREDICTION OF PITCH ANGULAR VELOCITY		0.217 [SEC]	
DETECTION TIME WITH NO PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY		0.309 [SEC]	
DETECTION TIME WITH PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY			
PREDICTION TIME T_p	INCLINATION MEASUREMENT TIME Δt_p		
	0.05 [SEC]	0.10 [SEC]	0.15 [SEC]
0.05[SEC]	0.230 [SEC]	0.234 [SEC]	0.238 [SEC]
0.10 [SEC]	0.197 [SEC]	0.201 [SEC]	0.207 [SEC]
0.15 [SEC]	0.162 [SEC]	0.172 [SEC]	0.184 [SEC]
0.20 [SEC]	0.135 [SEC]	0.146 [SEC]	0.166 [SEC]

FIG. 14

EXPERIMENT NO.		5	
FLANGE CLIMB SPEED		7.54km/H	
DETECTION TIME WITH NO PREDICTION OF PITCH ANGULAR VELOCITY		0.209 [SEC]	
DETECTION TIME WITH NO PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY		0.301 [SEC]	
DETECTION TIME WITH PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY			
PREDICTION TIME T_p	INCLINATION MEASUREMENT TIME Δt_p		
	0.05 [SEC]	0.10 [SEC]	0.15 [SEC]
0.05[SEC]	0.221 [SEC]	0.225 [SEC]	0.229 [SEC]
0.10 [SEC]	0.186 [SEC]	0.191 [SEC]	0.195 [SEC]
0.15 [SEC]	0.154 [SEC]	0.160 [SEC]	0.172 [SEC]
0.20 [SEC]	0.121 [SEC]	0.137 [SEC]	0.156 [SEC]

FIG. 15

EXPERIMENT NO.		6	
FLANGE CLIMB SPEED		8.11km/H	
DETECTION TIME WITH NO PREDICTION OF PITCH ANGULAR VELOCITY		0.195 [SEC]	
DETECTION TIME WITH NO PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY		0.271 [SEC]	
DETECTION TIME WITH PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY			
PREDICTION TIME T_p	INCLINATION MEASUREMENT TIME Δt_p		
	0.05 [SEC]	0.10 [SEC]	0.15 [SEC]
0.05[SEC]	0.207 [SEC]	0.209 [SEC]	0.211 [SEC]
0.10 [SEC]	0.164 [SEC]	0.170 [SEC]	0.180 [SEC]
0.15 [SEC]	0.131 [SEC]	0.141 [SEC]	0.156 [SEC]
0.20 [SEC]	0.104 [SEC]	0.123 [SEC]	0.141 [SEC]

FIG. 16

EXPERIMENT NO.		7	
FLANGE CLIMB SPEED		11.27km/H	
DETECTION TIME WITH NO PREDICTION OF PITCH ANGULAR VELOCITY		0.203 [SEC]	
DETECTION TIME WITH NO PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY		0.299 [SEC]	
DETECTION TIME WITH PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY			
PREDICTION TIME T_p	INCLINATION MEASUREMENT TIME Δt_p		
	0.05 [SEC]	0.10 [SEC]	0.15 [SEC]
0.05[SEC]	0.203 [SEC]	0.209 [SEC]	0.211 [SEC]
0.10 [SEC]	0.184 [SEC]	0.184 [SEC]	0.186 [SEC]
0.15 [SEC]	0.133 [SEC]	0.141 [SEC]	0.164 [SEC]
0.20 [SEC]	0.100 [SEC]	0.119 [SEC]	0.146 [SEC]

FIG. 17

EXPERIMENT NO.		8	
FLANGE CLIMB SPEED		11.85km/H	
DETECTION TIME WITH NO PREDICTION OF PITCH ANGULAR VELOCITY		0.215 [SEC]	
DETECTION TIME WITH NO PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY		0.301 [SEC]	
DETECTION TIME WITH PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY			
PREDICTION TIME T_p	INCLINATION MEASUREMENT TIME Δt_p		
	0.05 [SEC]	0.10 [SEC]	0.15 [SEC]
0.05[SEC]	0.223 [SEC]	0.229 [SEC]	0.232 [SEC]
0.10 [SEC]	0.188 [SEC]	0.193 [SEC]	0.201 [SEC]
0.15 [SEC]	0.164 [SEC]	0.168 [SEC]	0.182 [SEC]
0.20 [SEC]	0.131 [SEC]	0.148 [SEC]	0.168 [SEC]

FIG. 18

EXPERIMENT NO.		9	
FLANGE CLIMB SPEED		11.85km/H	
DETECTION TIME WITH NO PREDICTION OF PITCH ANGULAR VELOCITY		0.201 [SEC]	
DETECTION TIME WITH NO PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY		0.293 [SEC]	
DETECTION TIME WITH PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY			
PREDICTION TIME T_p	INCLINATION MEASUREMENT TIME Δt_p		
	0.05 [SEC]	0.10 [SEC]	0.15 [SEC]
0.05[SEC]	0.211 [SEC]	0.217 [SEC]	0.221 [SEC]
0.10 [SEC]	0.176 [SEC]	0.182 [SEC]	0.189 [SEC]
0.15 [SEC]	0.150 [SEC]	0.156 [SEC]	0.170 [SEC]
0.20 [SEC]	0.119 [SEC]	0.137 [SEC]	0.156 [SEC]

FIG. 19

EXPERIMENT NO.		4	
FLANGE CLIMB SPEED		7.5km/H	
DETECTION TIME WITH NO PREDICTION OF PITCH ANGULAR VELOCITY		0.217 [SEC]	
DETECTION TIME WITH NO PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY		0.309 [SEC]	
DETECTION TIME WITH PREDICTION OF MOVEMENT AVERAGE OF ROLL ANGULAR VELOCITY			
PREDICTION TIME T_p	INCLINATION MEASUREMENT TIME Δt_p		
	0.05 [SEC]	0.10 [SEC]	0.15 [SEC]
0.05[SEC]	0.174 [SEC]	0.180 [SEC]	0.186 [SEC]
0.10 [SEC]	0.146 [SEC]	0.154 [SEC]	0.164 [SEC]
0.15 [SEC]	0.123 [SEC]	0.137 [SEC]	0.148 [SEC]
0.20 [SEC]	0.105 [SEC]	0.121 [SEC]	0.137 [SEC]

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/064345

A. CLASSIFICATION OF SUBJECT MATTER

B61K13/00(2006.01)i, G01M17/007(2006.01)i, G01M17/08(2006.01)i, G08B21/00(2006.01)i, G08B31/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B61K13/00, G01M17/007, G01M17/08, G08B21/00, G08B31/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2014

Kokai Jitsuyo Shinan Koho 1971-2014 Toroku Jitsuyo Shinan Koho 1994-2014

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2010/064453 A1 (West Japan Railway Co.), 10 June 2010 (10.06.2010), paragraphs [0005], [0021], [0037] & EP 2374686 A1	1-2, 4-7
Y	JP 2004-255979 A (Denso Corp.), 16 September 2004 (16.09.2004), paragraphs [0005] to [0007] & US 2004/0199317 A1	1-2, 4-7
A	US 2002/0077733 A1 (Andre C. BIDAUD), 20 January 2002 (20.01.2002), entire text; all drawings & US 6347265 B1 & US 2004/0122569 A1 & WO 2003/069064 A1 & CA 2474757 A & AU 2002258076 A & CA 2489980 A	1-7

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search
11 August, 2014 (11.08.14)

Date of mailing of the international search report
26 August, 2014 (26.08.14)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/064345

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2000-006807 A (Hitachi, Ltd.), 11 January 2000 (11.01.2000), entire text; all drawings (Family: none)	1-7
A	JP 2011-245917 A (Hitachi, Ltd.), 08 December 2011 (08.12.2011), entire text; all drawings (Family: none)	1-7
A	JP 2004-090848 A (Nippon Sharyo, Ltd.), 25 March 2004 (25.03.2004), entire text; all drawings (Family: none)	1-7

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2010064453 A [0003]
- JP 2013113265 A [0044]